RECENT CHARM RESULTS FROM CLEO

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We describe two recent results using data collected with the CLEO detector at the CESR e^+e^- collider at energies near the $\Upsilon(4S)$. The first is a Dalitz plot analysis of the decay $D^0 \to K^0_S\pi^+\pi^-$. We observe a rich structure including the decay $D^0 \to K^{*+}\pi^-$ which may be produced by $D^0 - \overline{D^0}$ mixing or doubly Cabibbo-suppressed decays. We also search for $D^0 - \overline{D^0}$ mixing in the decay $D^0 \to K^{*+}e^-\overline{\nu}_e$. We observe no events and limit the mixing parameter $R_{\rm mix}$ to be less than 0.87% at the 95% confidence level.

1 Introduction

$D^0 - \overline{D^0}$ mixing arises from a mass difference or width difference in the mass eigenstates. The mixing amplitudes from these contributions are given by $x \equiv \Delta M/\Gamma_D$ and $y \equiv \Delta\Gamma/2\Gamma_D$, where ΔM and $\Delta\Gamma$ are the mass and width differences between the mass eigenstates, respectively, and Γ_D is the width of the D meson. The existence of a massive non-standard model particle could lead to an observable enhancement of x [1]. These measurements are complementary to measurements of mixing in the K^0 and $B^0_{(s)}$ systems in that only $D^0 - \overline{D^0}$ mixing would be sensitive to the existence of new down-type particles.

These analyses are based on 9 fb^{-1} of e^+e^- collisions produced in the CESR collider at energies near the $\Upsilon(4S)$ resonance and recorded using the CLEO II.V detector [2]. We use D^0 candidates from the decay $D^{*+} \to D^0\pi^+_s$ and use the charge of the slow pion ($\pi^\pm_s$) to tag whether the initial particle is a D^0 or $\overline{D^0}$. The possible final states of a D^0 decay are categorized as "right signed" (RS) if they contain an s quark (like $\overline{K^0}$ or K^-) and "wrong signed" (WS) if they contain an $\overline{s}$ quark (like K^0 or K^+). While not explicitly written, charge conjugate modes are implied here and throughout this paper. Cabibbo-favored (CF) decays are the only contribution to the RS final state. The WS final state may reached by x or y mixing or, for hadronic modes, by doubly Cabibbo-suppressed (DCS) decays. In hadronic decay channels, the

situation is complicated by a possible strong phase shift between the CF and DCS channels, which leads to observable variables x' and y', related to x and y by $x' = x\cos\delta_s + y\sin\delta_s$ and $y' = y\cos\delta_s - x\sin\delta_s$. Measurement of this strong phase shift is essential in order to resolve x and y [3]. Other WS hadronic decays of D^0 to $K^+\pi^-$, $K^+\pi^-\pi^0$, and $K^+\pi^-\pi^+\pi^-$ have been studied previously by CLEO [4,5,6].

CP violation in charm decays is predicted to be very small in the standard model. If CP violation were observed in charm decays, it would be strong evidence for new physics.

In addition to $D^0-\overline{D^0}$ mixing searches, multi-body D decays can be used study the spectroscopy of light mesons and glueball candidates using Dalitz plot analyses. These analyses are only possible with the large statistics D samples recently available and are complementary to previous studies.

2 Dalitz Plot Analysis of $D^0 \to K^0_S\pi^+\pi^-$

The decay $D^0 \to K^0_S\pi^+\pi^-$ may be used to search for $D^0-\overline{D^0}$ mixing and doubly Cabibbo-suppressed decays, to study the spectroscopy of light mesons and glueball candidates, and to understand the effects of final state interactions. In this paper we describe our observation of new decay submodes, including the WS decay $D^0 \to K^*(892)^+\pi^-$, in a fit of the Dalitz plot. Because the RS $K^*(892)^-\pi^+$ and WS $K^*(892)^+\pi^-$ intermediate states both decay to a common final state, they may interfere with each other. The phase of this interference can be extracted by fitting the Dalitz plot.

We reconstruct the K^0_S candidates in the $\pi^+\pi^-$ channel, where the pions are required to form a common vertex with a confidence level greater than 10^{-6}. We utilize the precision tracking of the CLEO II.V silicon vertex detector (SVX) [7] to refit the K^0_S, π^+, and π^- tracks to a common vertex and require the confidence level of the fit to exceed 10^{-4}. The π_s^+ track is refit with the constraint that it originate from the intersection of the D^0 candidate trajectory and the CESR luminous region.

In addition to the D^0 candidate mass, we also reconstruct the energy release in the D^{*+} decay, $Q \equiv M^* - M - m_\pi$, where M^* is the mass of the D^{*+} candidate, M is the mass of the D^0 candidate, and m_π is the mass of the charged pion. The distribution of Q has a core width of 220 ± 4 keV. The momentum of the D^{*+}candidate is required to be greater the 2.0 GeV/c. Our data selection results in 5299 candidate events within the signal region of three standard deviations about the central Q, M, and $m(\pi^+\pi^-)$ values. The fraction of background in the signal region is found to be quite small ($2.1 \pm 1.5\%$) using a fit to M.

The Dalitz plot variables used in the fit are $M^2(\pi^+\pi^-)$ and M_{RS}, where $M_{RS} = M(K^S_0\pi^-)$ for D^0 decays and $M_{RS} = M(K^S_0\pi^+)$ for $\overline{D^0}$ decays. The decay to a three-body $K^0_S\pi^+\pi^-$ final state is modeled as a pseudo-two-body decay in which one daughter is a resonance, followed by a two-body decay of the resonance. The Dalitz plot is fitted to the square of the sum of resonant and non-resonant amplitudes multiplied by complex coefficients. Each resonant component is modeled by a relativistic Breit-Wigner amplitude multiplied by Blatt-Weisskopf form factors [8] for the D^0 and intermediate particle decay vertices and a factor to give the correct J-dependent angular distribution.

The efficiency function is determined using a sample of non-resonant Monte Carlo, and is found to be nearly uniform across the Dalitz plot. The Dalitz plot of the small background is determined using sideband regions five to ten standard deviations away from the signal in Q and M. These distributions are fitted to a two-dimensional polynomial and uncertainties are determined by varying the parameters by one standard deviation.

The Dalitz plot is fitted using a maximum likelihood technique. We consider non-resonant and 18 possible resonant contributions: $K^*(892)^-$, $K_0(1410)^-$, $K_0(1430)^-$, $K_2(1430)^-$, $K^*(1680)^-$, $K_3(1780)^-$, $\omega(792)$, $\rho(770)^0$, $\rho(1450)^0$, $\rho(1700)^0$, $\sigma(500)$, $f_0(980)$, $f_2(1270)$, $f_0(1370)$, $f_0(1500)$,

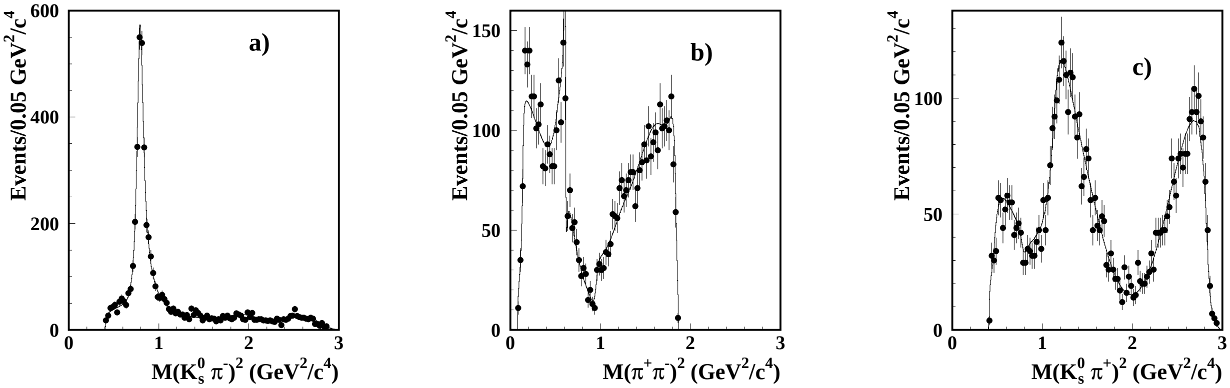

Figure 1: Projections of the Dalitz plot of $D^0 \to K^0_S\pi^+\pi^-$ in a) $M^2(K^0_S\pi^-)$, b) $M^2(\pi^+\pi^-)$, and c) $M^2(K^0_S\pi^+)$ showing the data (points) and fit function (line).

$f_0(1710)$, $K^*(892)^+$, $K_0(1430)^+$. The Dalitz plot and projections showing the fit results plotted against the data are shown in Fig. 1. The results of the nominal fit are shown in Tab. 1. An amplitude for the WS decay mode $D^0 \to K^*(892)^+\pi^-$ is observed with a statistical significance of 4.5 standard deviations. This is the first observation of this WS decay.

Systematic uncertainties on amplitudes and phases arise from uncertainties in the choice of resonances used in the fit, modeling of the decays, and experimental limitations. In particular, there are uncertainties associated with our poor understanding of $\pi\pi$ scalar resonances and threshold effects. The fit strongly prefers a feature consistent with the $\sigma(500)$, however, our Breit-Wigner parameterization of this contribution is inadequate for the purpose of establishing its existence. A partial wave analysis would be required. We try several fits with different contributions included or excluded in order to estimate the systematic uncertainty on the WS contribution.

We observe the WS decay mode $D^0 \to K^*(892)^+\pi^-$ and measure its branching fraction and strong phase shift relative to the RS decay $D^0 \to K^*(892)^-\pi^+$ to be $R_{WS} = (0.6 \pm 0.3 \pm 0.2)\%$ and $(-3 \pm 11 \pm 8)^\circ$, respectively. D^0 and $\overline{D^0}$ decays are also analyzed separately and no CP violating effects are observed at the few percent level.

3 Limit on $D^0 - \overline{D^0}$ Mixing Using $D^0 \to K^{*+}e^-\overline{\nu}_e$

The decay mode $D^0 \to K^{*+}e^-\overline{\nu}_e$ is sensitive to $R_{mix} \equiv \frac{1}{2}(x^2 + y^2)$, but not to x directly. While there are experimental difficulties related to the undetected neutrino and soft spectra of the daughter tracks, only mixing contributes to the WS final state.

The K^{*+} is reconstructed in the $K^0_S\pi^+$ mode, where the $\pi^+\pi^-$ final state is used to reconstruct the K^0_S. The neutrino is "pseudo-reconstructed", taking advantage of the hermeticity of the CLEO detector in order to improve the resolution on Q. The direction of the neutrino is taken from a weighted average of the event thrust axis, the slow pion direction, and the direction of all D^0 daughters other than the neutrino. The optimal weights of these measurements is based on Monte Carlo simulations. The remaining quadratic ambiguity on the momentum is resolved by considering the choice which gives the most probable combination of D^0 momentum and electron decay angle in the W rest frame.

A maximum likelihood fit to the candidate Q and proper time is used to determine the signal contribution. The proper time for signal is expected to have a t^2e^{-t} dependence, where t is the proper time normalized to the D^0 lifetime. The fit to the RS data yields 638 ± 51 events. The WS fit yields 0.00 ± 1.99 events, leading to an upper limit on R_{mix} of <0.87% at 95% confidence

Table 1: Results of the Dalitz plot fit of the decay $D^0 \to K_S^0\pi^+\pi^-$. The first uncertainty is statistical, the second is the experimental systematic uncertainty, the third is due the choice of the resonance model and which resonances are included in the fit.

Submode	Amplitude	Phase (°)	Fit Fraction
$K^*(892)^+$	$0.131 \pm 0.029\ ^{+0.050}_{-0.016}\ ^{+0.054}_{-0.030}$	$152 \pm 11\ ^{+5}_{-8}\ ^{+4}_{-11}$	0.0041 ± 0.0020
$\rho(770)^0$	1.0 (fixed)	0 (fixed)	0.227 ± 0.011
$\omega(792)$	$0.055 \pm 0.006 \pm 0.01\ ^{+0.005}_{-0.006}$	$117 \pm 7 \pm 4\ ^{+3}_{-8}$	0.013 ± 0.003
$K^*(892)^-$	$1.68 \pm 0.05 \pm 0.04\ ^{+0.05}_{-0.07}$	$149 \pm 2\ ^{+3}_{-2}\ ^{+3}_{-5}$	0.672 ± 0.014
$f_0(980)$	$0.36 \pm 0.02\ ^{+0.06}_{-0.03}\ ^{+0.06}_{-0.02}$	$185 \pm 5\ ^{+1}_{-3}\ ^{+19}_{-9}$	0.040 ± 0.005
$f_2(1270)$	$0.8 \pm 0.2\ ^{+0.2}_{-0.3}\ ^{+0.8}_{-0.2}$	$368 \pm 21 \pm 13 \pm 27$	0.006 ± 0.002
$f_0(1370)$	$1.56 \pm 0.14\ ^{+0.24}_{-0.010}\ ^{+0.7}_{-0.5}$	$74 \pm 6\ ^{+2}_{-17}\ ^{+21}_{-11}$	0.07 ± 0.01
$K_0(1430)^-$	$2.2 \pm 0.1\ ^{+0.1}_{-0.2} \pm 0.4$	$11 \pm 5\ ^{+6}_{-5}\ ^{+10}_{-22}$	0.080 ± 0.009
$K_2(1430)^-$	$0.9 \pm 0.1^{+0.3}_{-0.0} \pm 0.4$	$-47 \pm 8 \pm 6^{+19}_{-11}$	0.015 ± 0.002
$K^*(1680)^-$	$5.6 \pm 0.8 \pm 0.9^{+2.8}_{-4.2}$	$173 \pm 8 \pm 12^{+18}_{-20}$	0.023 ± 0.006
Non-resonant	$1.9 \pm 0.6\ ^{+0.6}_{-0.4}\ ^{+1.4}_{-0.9}$	$-30 \pm 11\ ^{+16}_{-7}\ ^{+16}_{-7}$	0.027 ± 0.016

level.

4 Outlook

Several searches for $D^0-\overline{D^0}$ mixing and studies of light meson spectroscopy using Dalitz analyses of D decays are underway at CLEO. We expect to have public results of a *time-dependent* Dalitz analysis of $D^0 \to K_S^0\pi^+\pi^-$ in the near future . Since δ_s is measured, x and y are measured directly. Furthermore, this is the only analysis with sensitivity to the sign of x. The $D^0 \to K^{*+}e^-\overline{\nu}_e$ result will be combined with results of an analysis of $D^0 \to K^+\ell^-\overline{\nu}_\ell$ which is underway.

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